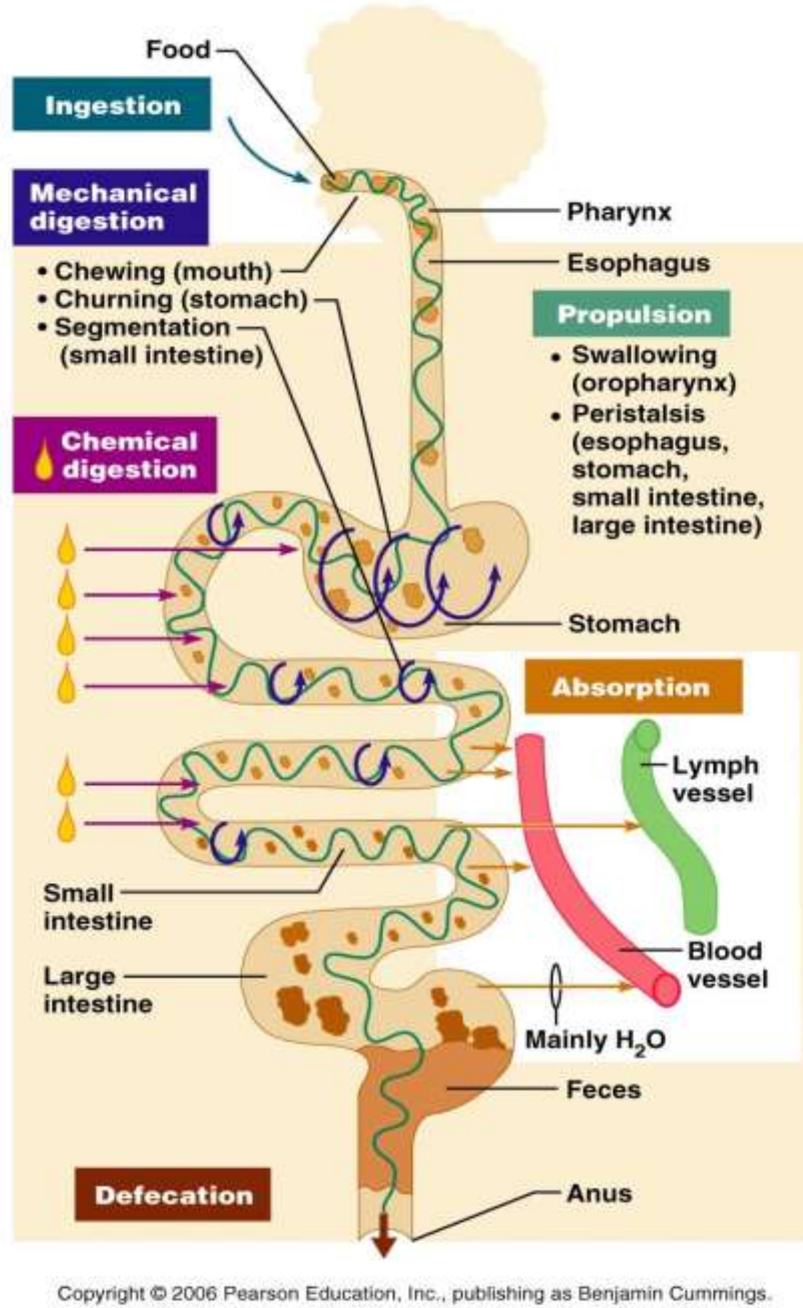
The Digestive System

Dr. Ali Ebneshahidi

Functions of the Digestive System

- **ingestion** – the oral cavity allows food to enter the digestive tract and have mastication (chewing) occurs , and the resulting food bolus is swallowed .
- **Digestion:**
- Mechanical digestion – muscular movement of the digestive tract (mainly in the oral cavity and stomach) physically break down food into smaller particles .
- chemical digestion – hydrolysis reactions aided by enzymes (mainly in the stomach and small intestine) chemically break down food particles into nutrient molecules , small enough to be absorbed . .

- **Secretion** – enzymes and digestive fluids secreted by the digestive tract and its accessory organs facilitate chemical digestion .
- **Absorption** – passage of the end – products (nutrients) of chemical digestion from the digestive tract into blood or lymph for distribution to tissue cells .
- **Elimination** – undigested material will be released through the rectum and anus by defecation .



Organization of The Digestive System

- Organs of the digestive system are divided into 2 main group : the **gastrointestinal tract (GI tract)** and **accessory structures** .

- GI tract is a continuous tube extending through the ventral cavity from the mouth to the anus – it consists of the mouth , oral cavity , oropharynx , esophagus , stomach , small intestine , large intestine , rectum , and anus .

- Accessory structures include the teeth, tongue (in oral cavity) , salivary glands , liver , gallbladder , and pancreas .

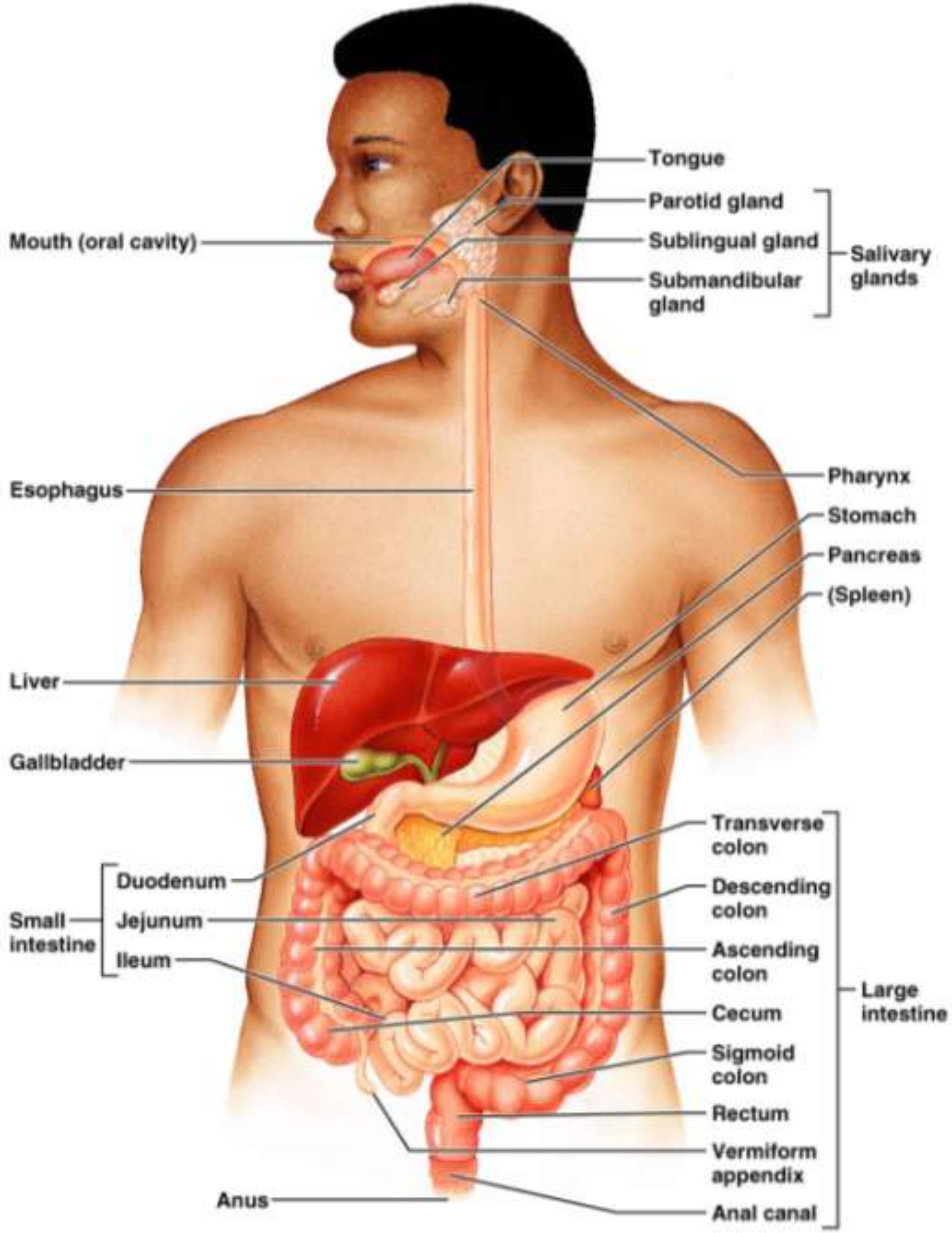

Tongue
Parotid gland
Mouth (oral cavity)
Sublingual gland
Submandibular gland
Salivary glands
Pharynx
Esophagus
Stomach
Pancreas
(Spleen)
Liver
Gallbladder
Transverse colon
Duodenum
Descending colon
Small intestine
Jejunum
Ileum
Ascending colon
Large intestine
Cecum
Sigmoid colon
Rectum
Vermiform appendix
Anus
Anal canal

Figure 23.1

Muscular movement of the GI tract

- **Peristalsis** – wavelike movement that occurs from the oropharynx to the rectum , allowing GI tract to push food particles toward the anus .
- **Mixing**—mixing motion in the oral cavity and stomach that allows the GI tract to repeatedly break down food into smaller particles , using mechanical digestion .
- **Segmentation** – regions of the small intestine contracting and relaxing independently , allowing the small intestine to digestive and absorb more efficiently .

Histology of the Alimentary Canal

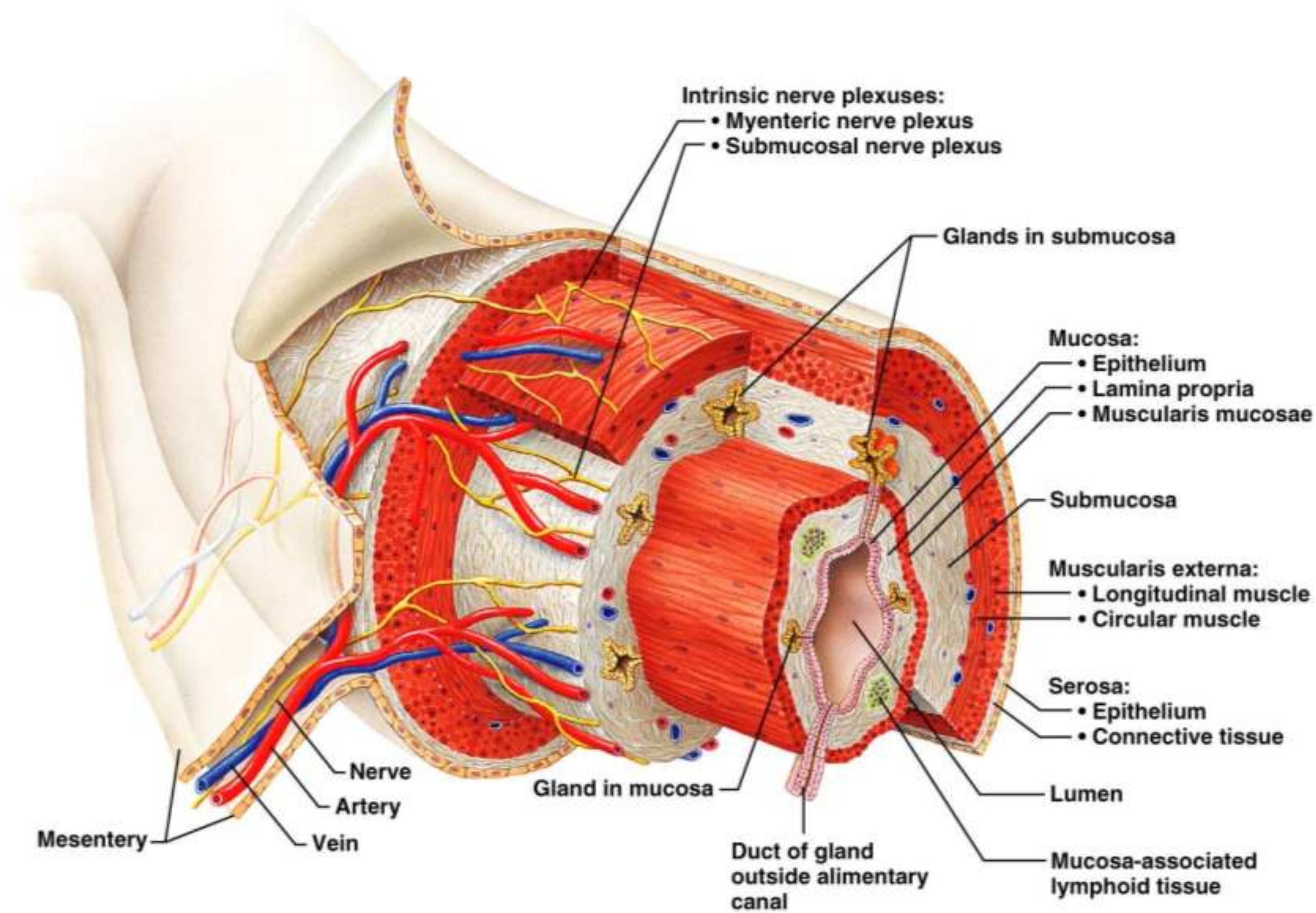


Figure 23.6

Peristalsis and Segmentation

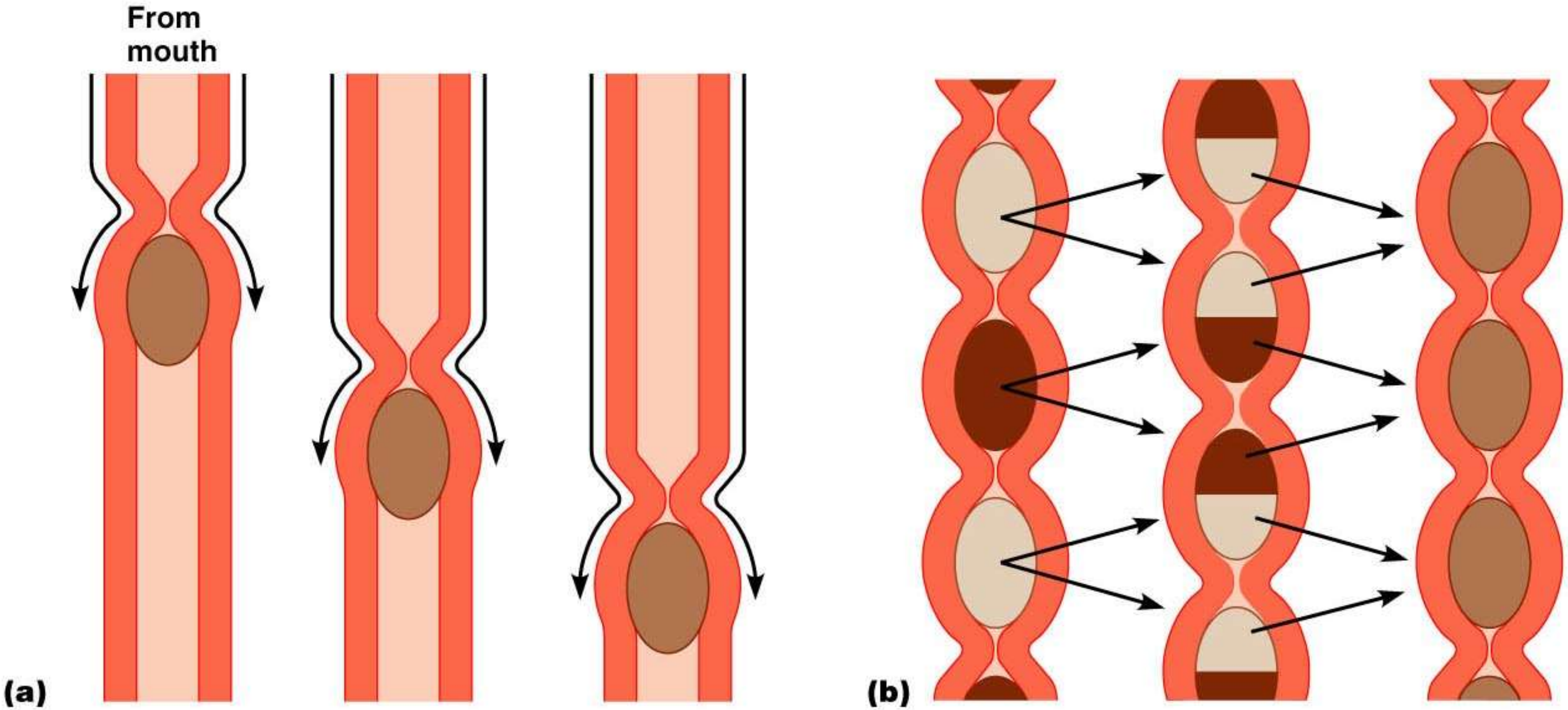
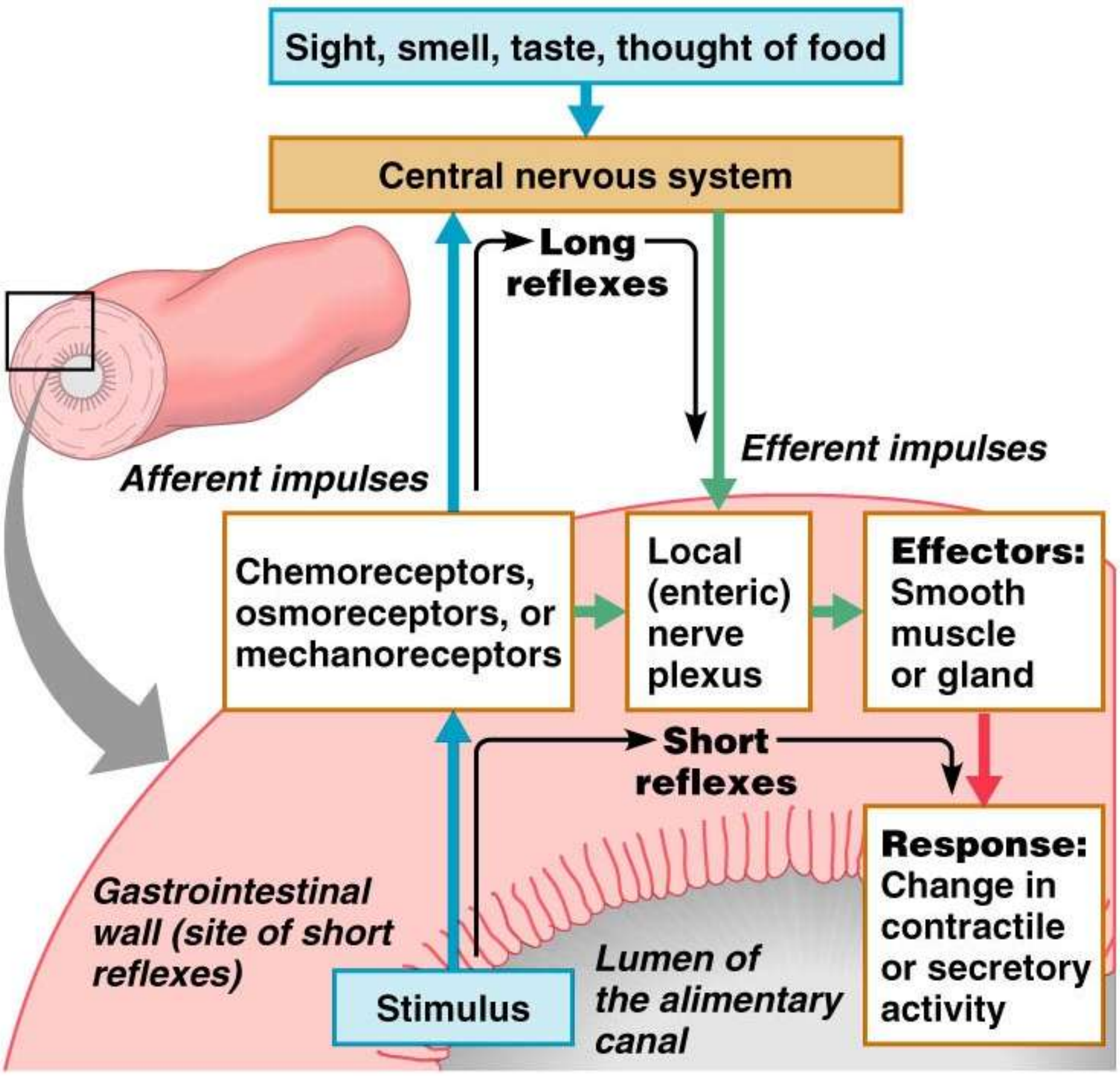


Figure 23.3

Regulation of GI Tract Activities

- **Autonomic nervous system**
  - - parasympathetic nerves stimulate GI tract activities .
  - - sympathetic nerves inhibit GI tract activities .
- **Hormonal control**
  - - hormones from endocrine gland and from GI tract itself help regulate GI tract activities .
- **Reflex mechanism**
  - - regions of the GI tract (especially the stomach and small intestine) use reflexes to stimulate or inhibit one another .

Nervous Control of the GI Tract

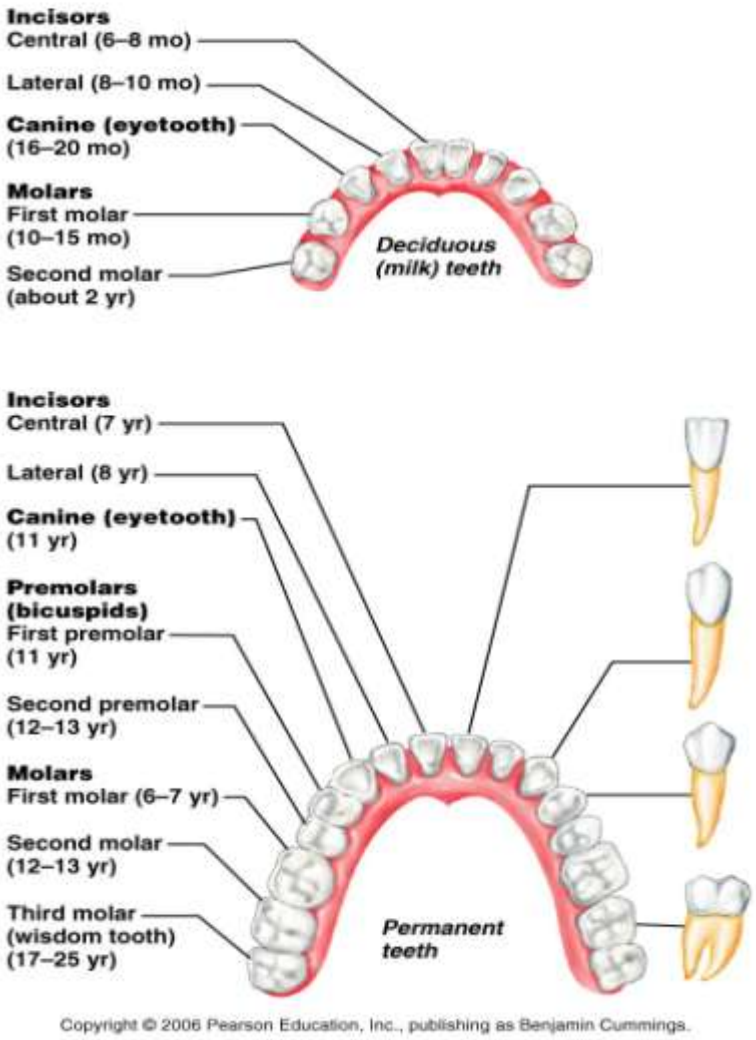


Mouth & Oral Cavity

- Food enters the GI tract by ingestion .
- Food is broken down by mechanical digestion , using mastication .
- One chemical digestive process occur where **amylase** enzyme in saliva breaks down polysaccharide into disaccharides .
- The **tongue** , made of skeletal muscle, manipulates the food during mastication . it also contains taste buds to detect taste sensations(intrinsic) .
- Food particles are mixed with saliva during mastication , resulting in a moist lump called **bolus** for easier passage into or pharynx .

Teeth

- Adapted for **mechanical digestion** (mastication) in the oral cavity .
- 20 deciduous or primary teeth before the age of 6.
- By age 7, 32 permanent or secondary teeth are developed & are divided into 4 types: **incisors** (for cutting) , **Canines** (for tearing) , **Premolars** (for crushing), and **Molars** (for grinding). these teeth follow the human dental formula of 2-1-2-3.



Salivary Glands

- 3 pairs of salivary glands called **parotid** , **submandibular** , and **sublingual** gland secrete most of the saliva in the oral cavity , using salivary ducts .
- Saliva helps moisten the food during mastication , dissolve the food in forming the bolus , and help cleanse the teeth.
- Saliva consists of 99.5% water , the remaining 0.5% is dissolved substances including **amylase** enzyme (for chemically digesting carbohydrate), bicarbonate ion (HCO_3^-; maintains pH of saliva at 6.5-7.5) , and many electrolytes.

Salivary Glands

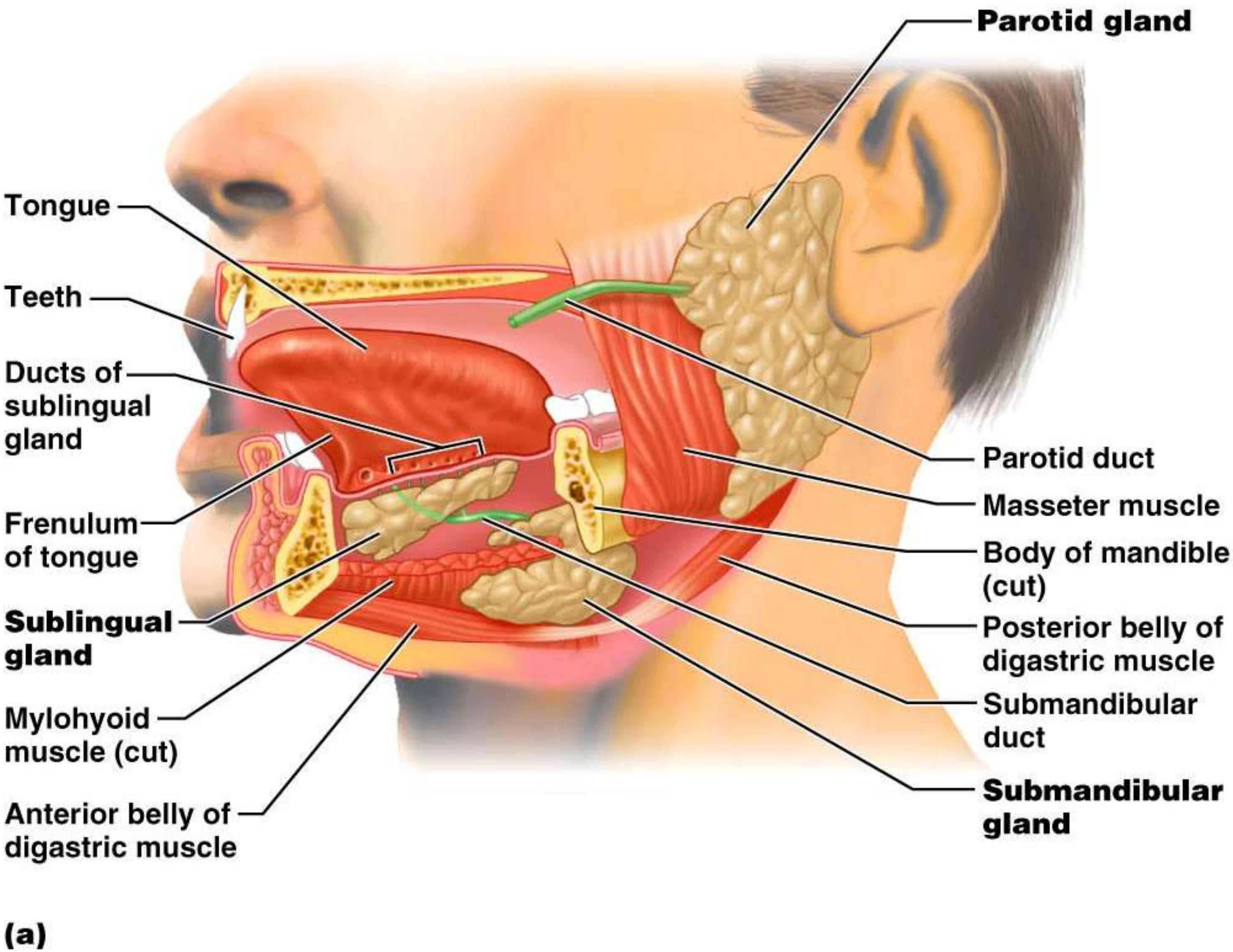
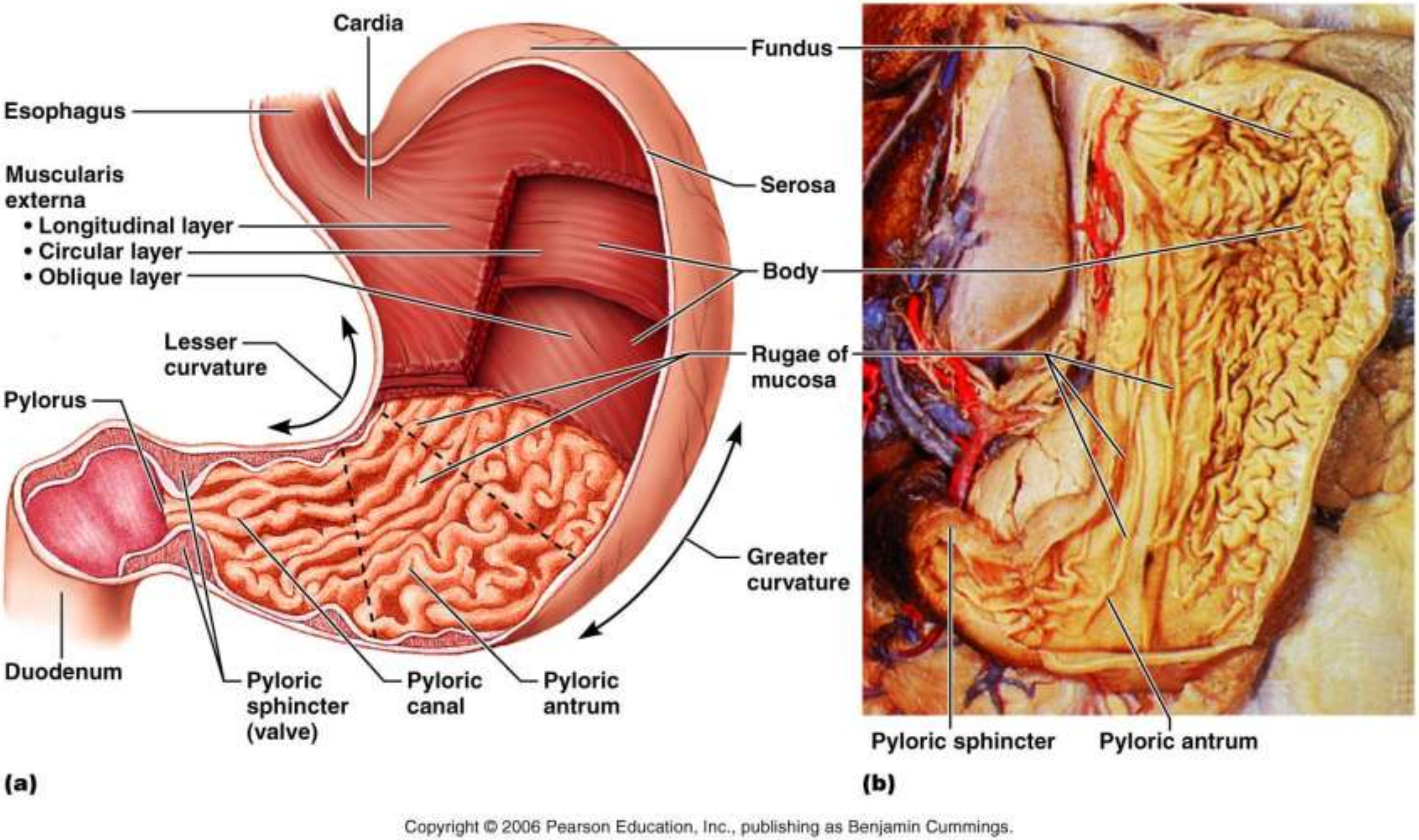


Figure 23.9a

Stomach

- A pouch-like organ primarily designed for food storage (for 2-4 hours) , some mechanical and chemical digestion also occur .
- Contains two sphincters at both ends to regulate food movement – **cardiac sphincter** near the esophagus ,and **pyloric sphincter** near the small intestine .
- Divided into 4 regions : **cardiac stomach** (or cardiac), **fundic stomach** (or funded) , **body of stomach** , and **pyloric stomach** (or Pylorus).
- Contain thick folds called **rugae** at its layer , for providing larger surface area for expansion , secretion , digestion , and some absorption.

Stomach

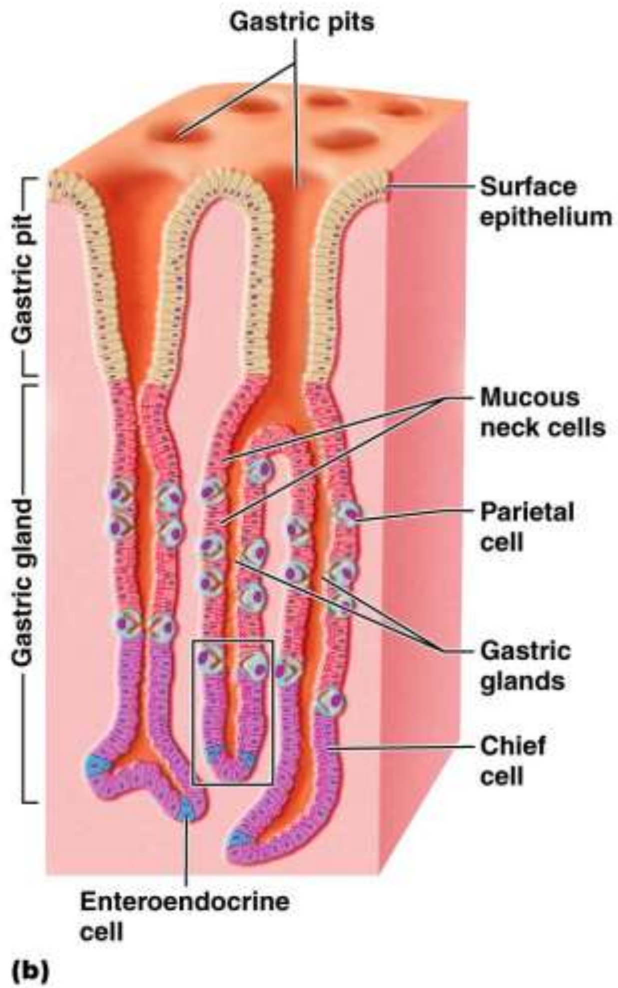


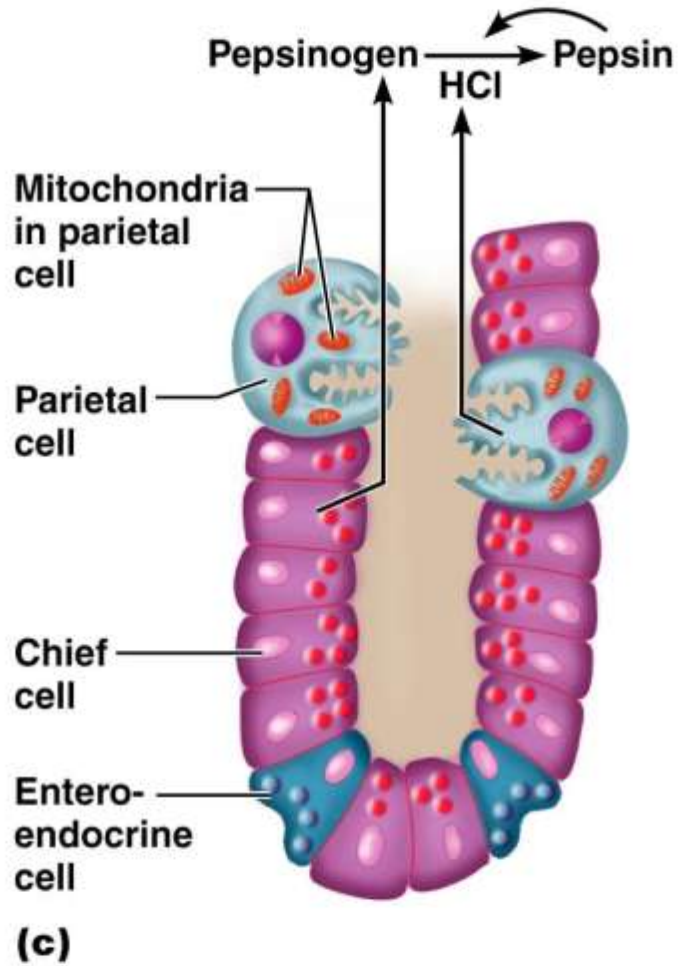
Cardia
Fundus
Esophagus
Serosa
Muscularis externa
• Longitudinal layer
• Circular layer
• Oblique layer
Body
Lesser curvature
Rugae of mucosa
Pylorus
Greater curvature
Duodenum
Pyloric sphincter (valve)
Pyloric canal
Pyloric antrum
(a)
Pyloric sphincter
Pyloric antrum
(b)
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Gastric Secretory Cells

- -**Chief cells:** secrete pepsinogen (an inactive enzyme).
- -**Parietal cells:** secrete hydrochloric and (HCl) and "intrinsic factor" (which helps absorption of vitamin B_{12} in the intestines).
- - **Mucous cells:** secrete mucus and alkaline substances to help neutralize HCl in the gastric juice .
- -**G cells:** secrete a hormone called gastrin , which stimulates the parietal cells and overall gastric secretion .

Gastric Cells





Chemical digestion & absorption in the stomach

- - Carbohydrate digestion is continued with **gastric amylase** , resulting in disaccharides .
- - Protein digestion begins with **pepsin** (activation of pepsinogen by HCl) , resulting in peptides (small chains of protein).
- - Lipid digestion begins with **gastric lipases** which can only break down certain lipids such as butterfat , resulting in fatty acids .
- Absorption in the stomach is limited, where only small and fat-soluble substances can be absorbed—water , alcohol, aspirin , and certain drugs .
- The result of all these mixing , chemical digestion , secretion, and absorption is a yellowish paste called **chyme** , which will be passed on to the small intestine .

Regulation of Gastric Secretion

- Regulation of gastric secretion and activities is by both nervous and hormonal mechanisms – food moving along the oral cavity and esophagus stimulates the **parasympathetic nerves** to activate the secretion in gastric glands , the **gastric hormone** from G cells in turn stimulates the gastric glands for more activities ("positive feedback").
- On the other hand , when food is emptying from the stomach , **sympathetic nerves** inhibit the gastric glands and gastric , and a hormone called **intestinal gastrin** (released by small intestine) inhibits other gastric activities.
- The above regulations occur in 3 overlapping phases:
- **Cephalic Phase**, **Gastric Phase,** & Intestinal Phase.

Cephalic phase

- **Cephalic phase:** involves special senses detect food and uses parasympathetic nerves in the vagus nerve to stimulate gastric activities.
- 1. Sight, Smell , and Taste of food cause stimulation of vagus nuclei in brain.
- 2. Vagus stimulates acid secretion.
- a. Direct stimulation of parietal cells (major effect).
- b. Stimulation of Gastrin secretion (lesser effect).

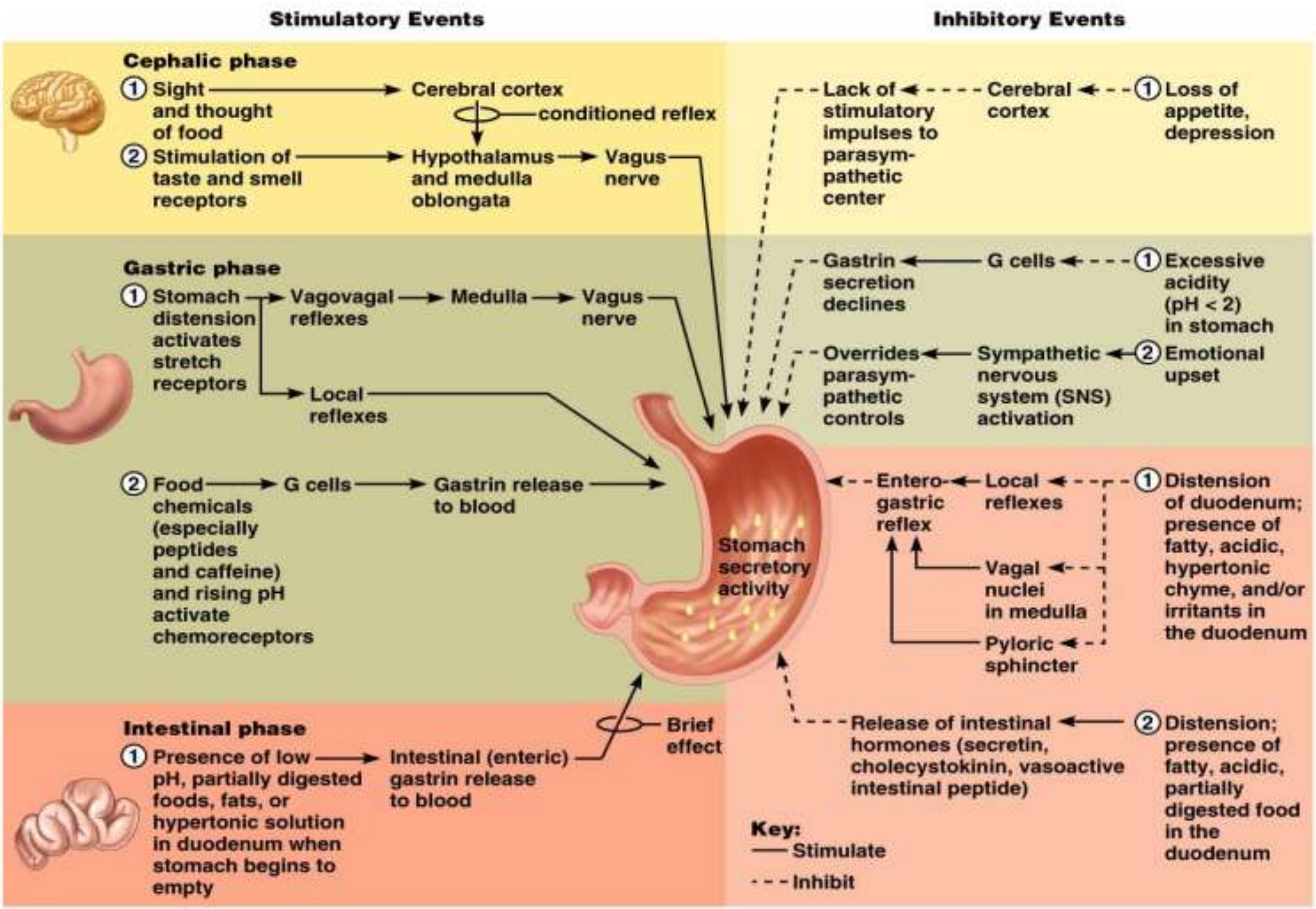
Gastric phase

- **Gastric phase** involves the distention of stomach and stimulates its own activities by the vagus nerve. Distension of stomach (stretch - receptors) stimulates vagus nerve ; vagus stimulates acid secretion .
- Amino acids and peptides in stomach lumen srimulates acid secretion (chemo - receptors)
- Direct stimulation of parietal cells (lesser effect)
- Stimulation of gastrin secretion ; gastrin stimulates acid secretion (major effect)
- Gastrin secretion inhibited when PH of gastric juice falls below 2.5.

Intestinal Phase

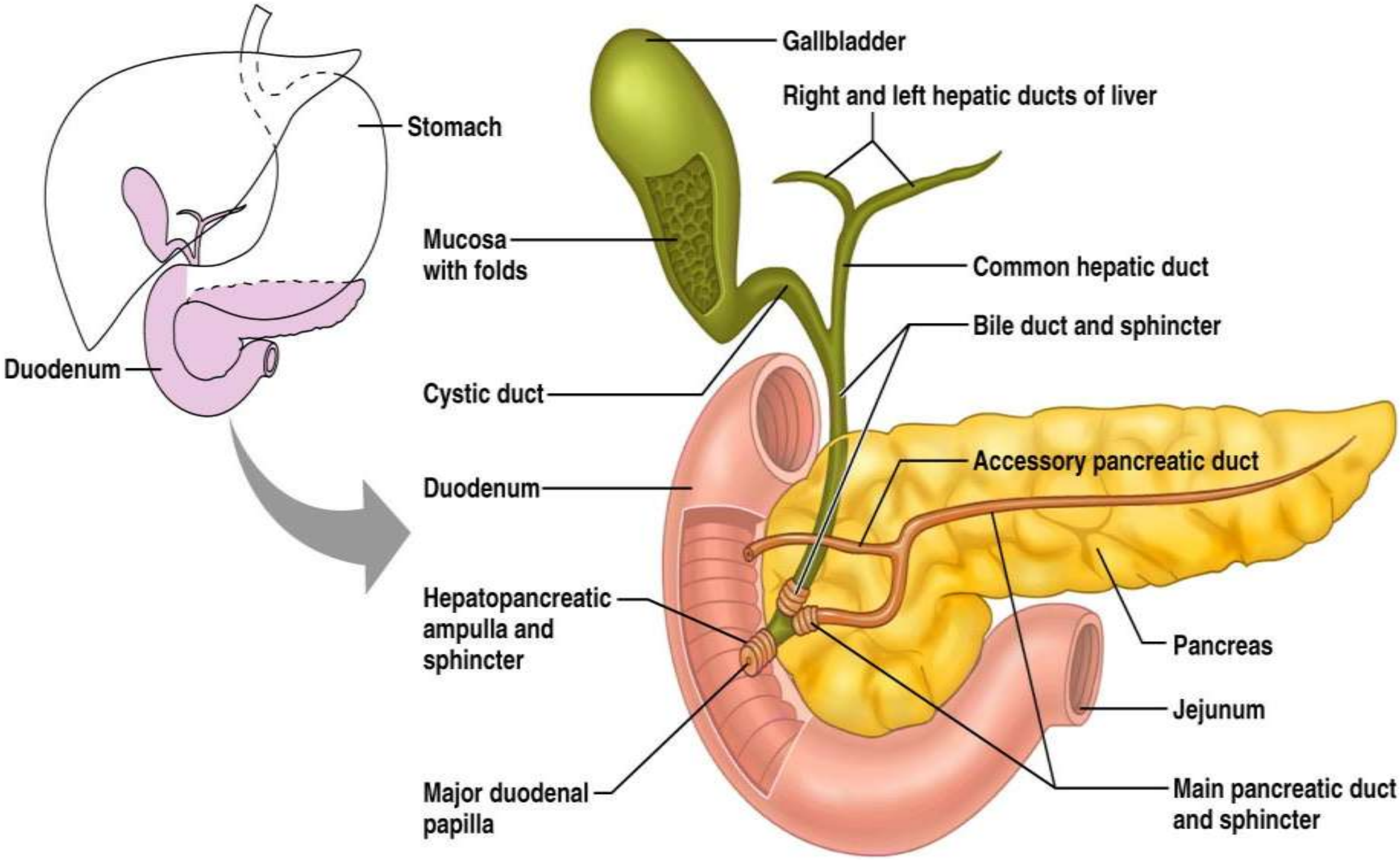
- **intestinal phase** involves acidic chyme passing into the small intestine which secretes intestinal gastrin hormone to inhibit gastric activates.
- Neural inhibition of gastric emptying and acid secretion. Arrival of chyme in duodenum causes distension & an increase in osmotic pressure. These stimuli activate a neural reflex that inhibits gastric activity.
- In response to fat in chyme , duodenum secretes the hormone, **secretin** that inhibits gastric acid secretion.
- The enterogastric reflex: This reflex begins in the small intestine (entero) and ends in the stomach (gastro).
- Duodenum fills with chyme. Sensory stretch receptors are stimulated. Sensory nerve impulses travel to CNS. Nerve impulses from CNS (vagus) inhibit peristalsis in stomach wall.

Stomach: Neural & Hormonal Mechanisms



Pancreas

- Pancreas : most pancreatic enzymes are produced as inactivate molecules , or zymogens , so that the risk of self – digestion within the pancreas is minimized .
- More than 98% of the pancreas mass is devoted to its exocrine function: the secretion of pancreatic juice by the pancreatic acini and their ductile cells. Ductile cells produce **Sodium bicarbonate** which helps neutralize the acidic gastric contents .
- Acinar cells of the exocrine pancreas produce a variety of **digestive enzymes** to break down food substances into smaller absorbable molecules .
- Only 2% of pancreas mass is devoted to the islets of langerham , which produce **insulin** and **glucagon** , hormones that regulate blood sugar and carbohydrate metabolism (they have opposite effects) .

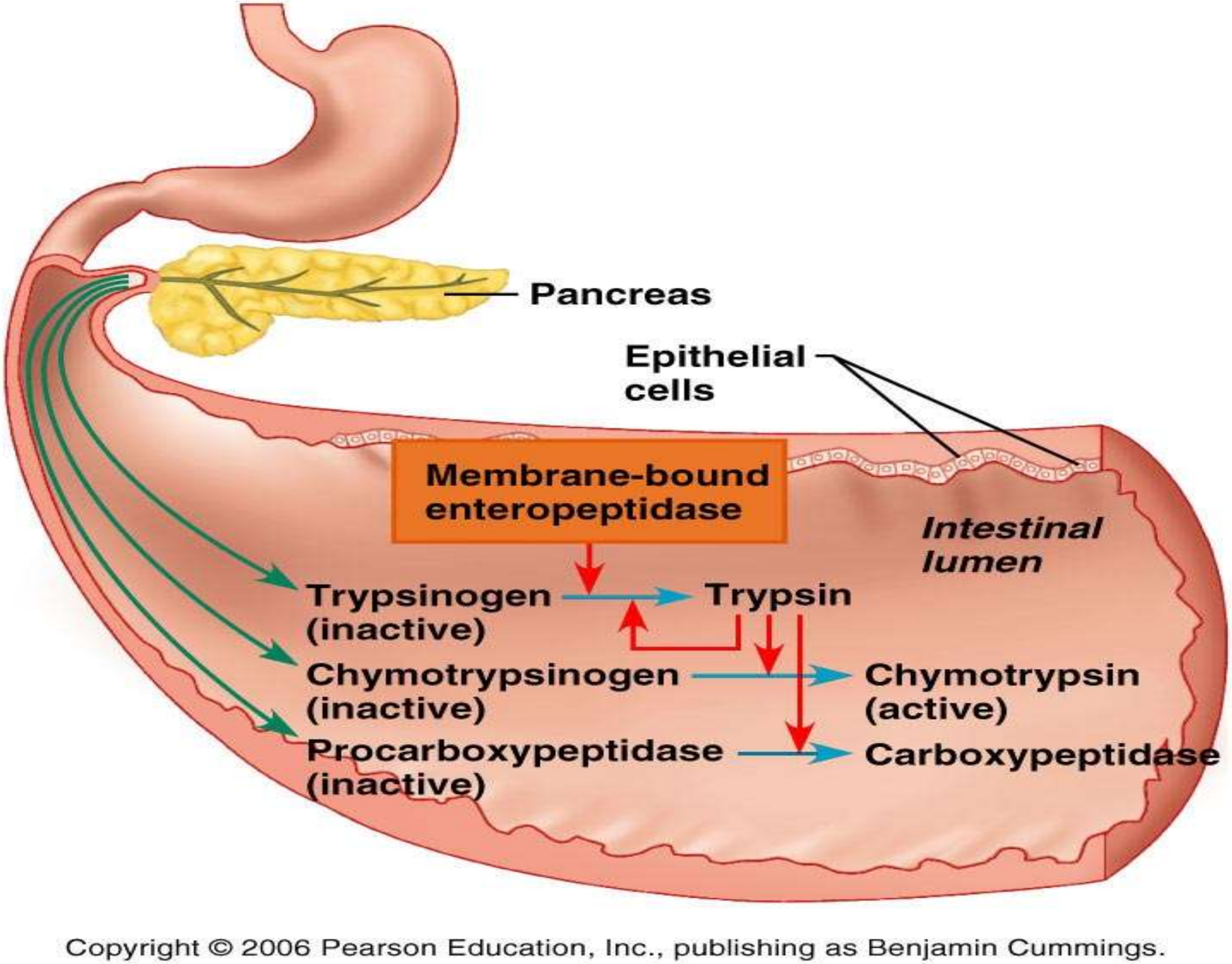

Gallbladder
Right and left hepatic ducts of liver
Stomach
Mucosa with folds
Common hepatic duct
Bile duct and sphincter
Duodenum
Cystic duct
Accessory pancreatic duct
Duodenum
Hepatopancreatic ampulla and sphincter
Pancreas
Jejunum
Major duodenal papilla
Main pancreatic duct and sphincter

Major pancreatic Enzymes

- -**pancreatic amylase:** digest polysaccharides into disaccharides
- - **pancreatic lipases** digest triglycerides into fatty acids .
- - **pancreatic nucleases** digest nucleic acids into nucleotides .
- -**Pancreatic proteinases** (all secreted in their inactive forms) digest peptides into amino acids:

  Trypsinogen is activated by enterokinase (secreted by duodenum) into **trypsin** , which in turn activates the other 3 enzymes – **chymo-trypsinogen** becomes **chymotrypisn** , **proaminopeptidase** becomes **aminopeptidase**, **and** **procarboxypeptidase** becomes **carboxypeptidase**.

Activation of pancreatic proteases in the small intestine

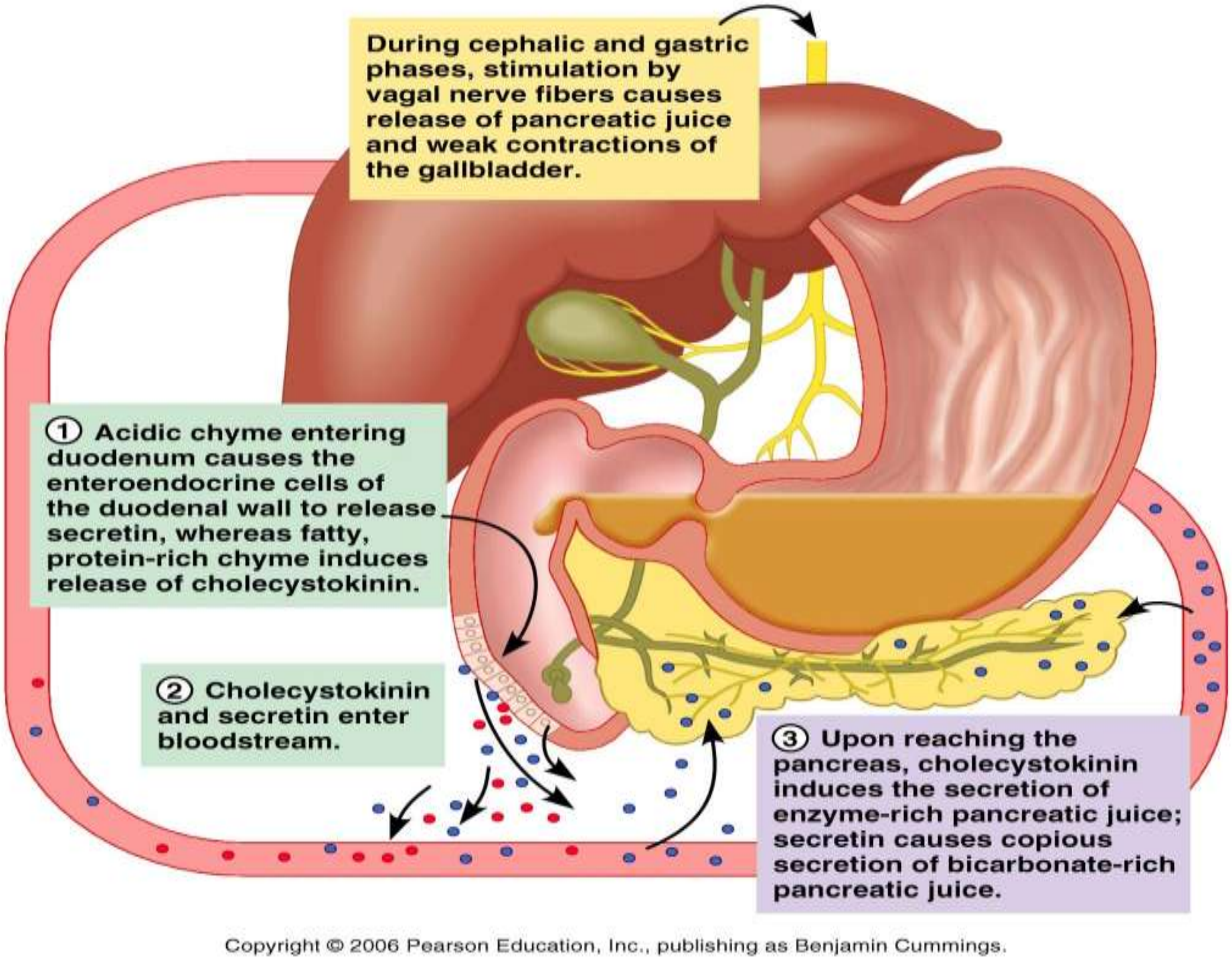


Pancreatic Secretion

- 1.The parasympathetic nervous system increases pancreatic secretion
- 2. Two duodenual hormones also influence pancreatic secretion: Secretin and Cholecystokinin.
- 3. Food entering the small intestine stimulates the secretion of both hormones.
- 4. Secretin stimulates the secretion of pancreatic electrolyte – rich fluid , while CCK enhances the enzymatic secretions of the pancreas .

Regulation of pancreatic Juice

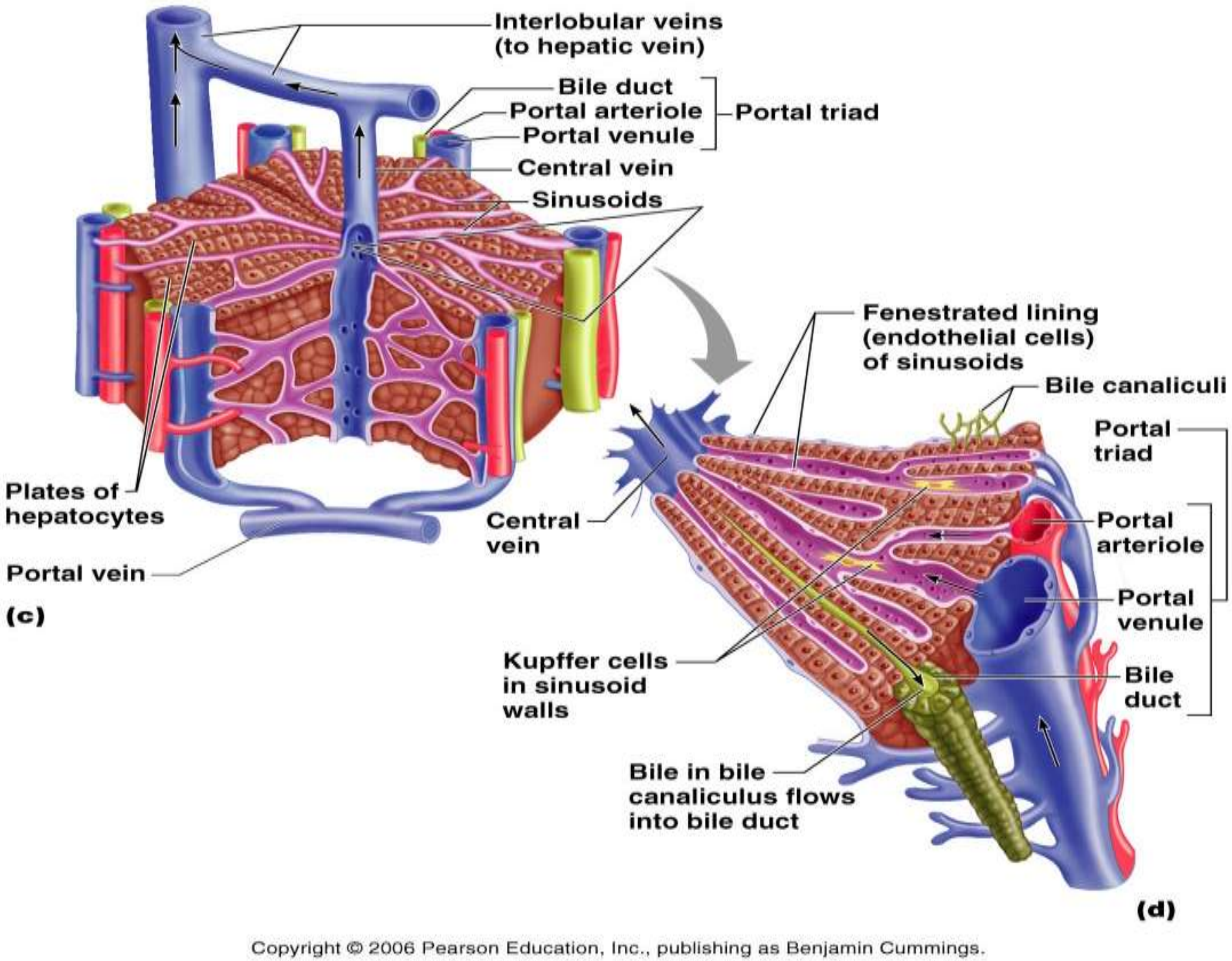
- 1. Acidic chyme enters duodenum.
- 2. Secretin is released into blood stream from intestinal mucosa.
- 3. Secretin stimulates pancreas.
- 4. Pancreas secretes pancreatic juice.
- 5. Pancreatic juice , high in bicarbonate ions , neutralizes acidic chyme.


During cephalic and gastric phases, stimulation by vagal nerve fibers causes release of pancreatic juice and weak contractions of the gallbladder.
① Acidic chyme entering duodenum causes the enteroendocrine cells of the duodenal wall to release secretin, whereas fatty, protein-rich chyme induces release of cholecystokinin.
② Cholecystokinin and secretin enter bloodstream.
③ Upon reaching the pancreas, cholecystokinin induces the secretion of enzyme-rich pancreatic juice; secretin causes copious secretion of bicarbonate-rich pancreatic juice.
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Functions of The Liver

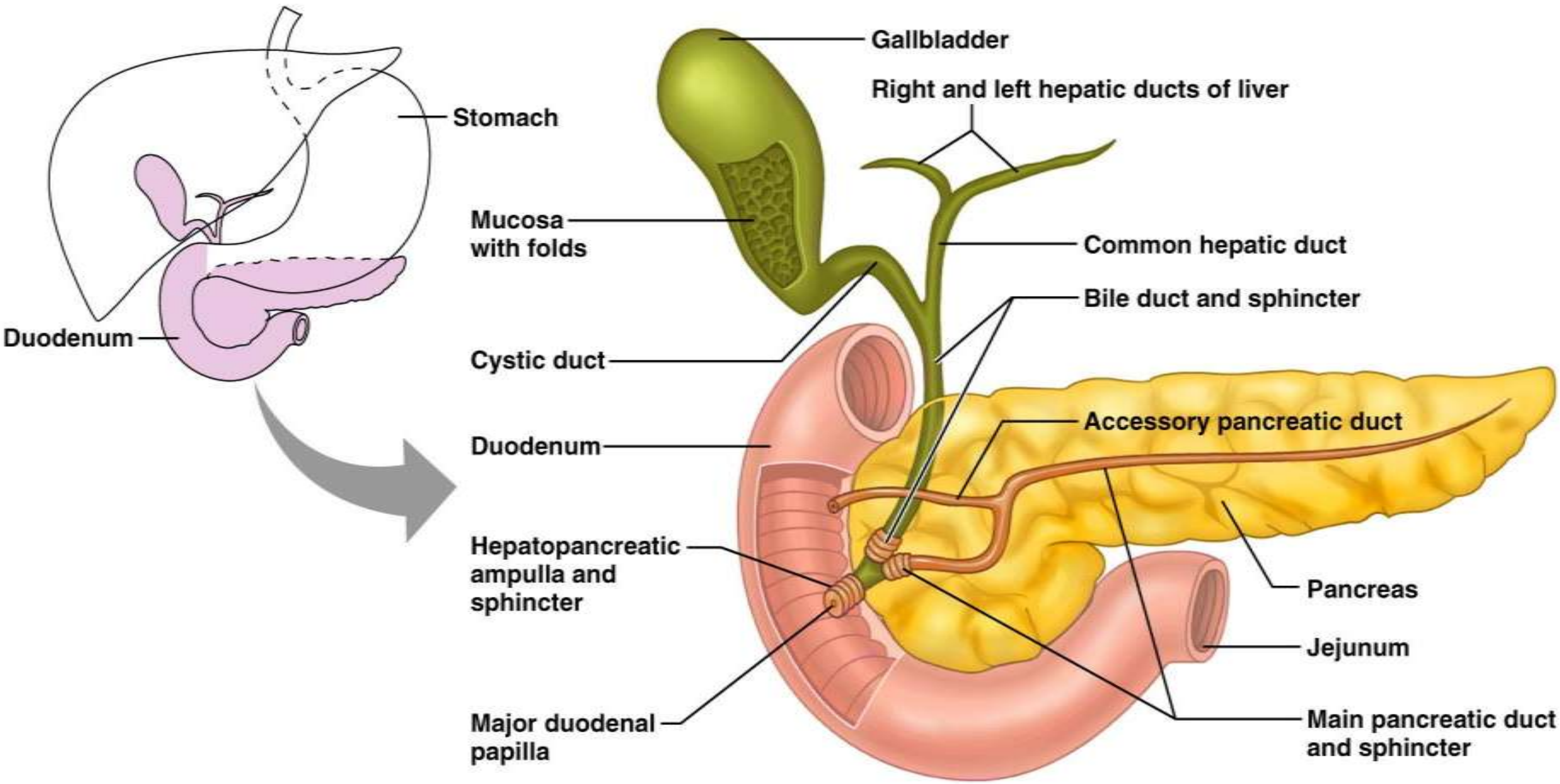
- Important in carbohydrate metabolism where hepatic cells conduct **glycogenesis** (converting glucose into glycogen) **,** and **glycogenolysis** (breaking glycogen down to glucose)**.**
- Also is critical in lipid metabolism where hepatic cells produce **bile** (for fat emulsification), oxidize fatty acids , synthesize various forms of lipids ,and convert glucose to fatty acids (**lipogenesis**) .
- Other functions of the liver include :
- \- Storage of glycogen, iron , and vitamins A,D,B_{12}.
- -Contains phagocytes to destroy damaged erythrocytes and foreign substances, using phagocytosis .
- -Detoxifies harmful substances in the blood .
- -Serves as a blood reservoir (contains 7% of blood volume).

Liver


Interlobular veins
(to hepatic vein)
Bile duct
Portal arteriole
Portal venule
Portal triad
Central vein
Sinusoids
Plates of
hepatocytes
Portal vein
(c)
Fenestrated lining
(endothelial cells)
of sinusoids
Bile canaliculi
Portal
triad
Central
vein
Portal
arteriole
Portal
venule
Bile
duct
Kupffer cells
in sinusoid
walls
Bile in bile
canaliculus flows
into bile duct
(d)
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Gall Bladder

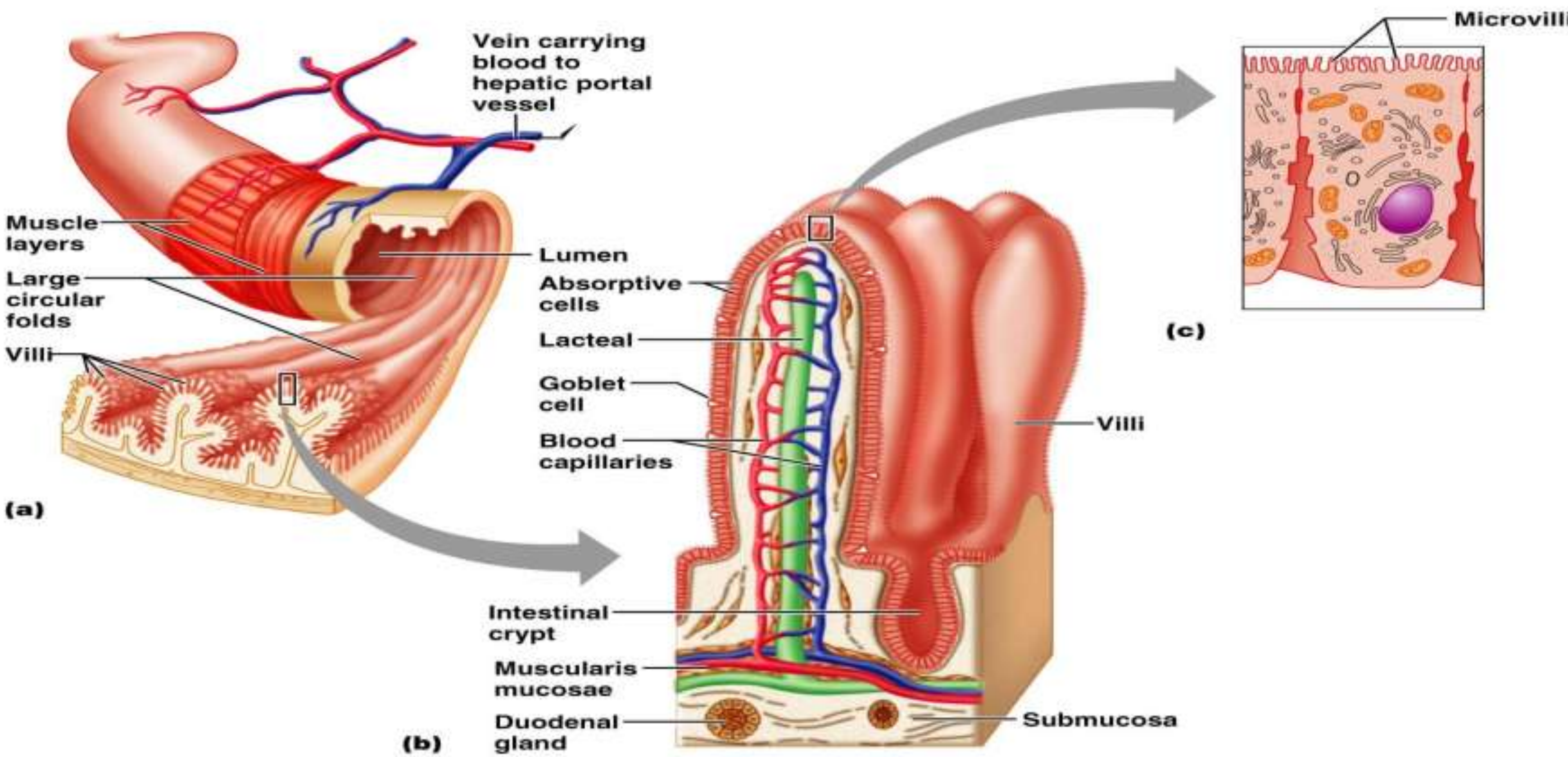
- A small sac located on the inferior , visceral surface of the liver.
- Stores and concentrates bile secreted by the liver.
- **Regulation of Bile Release:**
- 1. **Chyme** with fat enters small intestine.
- 2. Cells of intestinal mucosa secrete the hormone **Cholecystokinin** (CCK) into the blood stream.
- 3. **CCK** stimulates muscular layer of gallbladder wall to contract.
- 4. **Bile** passes down the cystic duct and common bile duct to duodenum .
- 5. Hepatopancreatic sphincter relaxes and **bile** enters duodenum.


Stomach
Duodenum
Gallbladder
Right and left hepatic ducts of liver
Mucosa with folds
Common hepatic duct
Bile duct and sphincter
Cystic duct
Accessory pancreatic duct
Duodenum
Hepatopancreatic ampulla and sphincter
Pancreas
Jejunum
Major duodenal papilla
Main pancreatic duct and sphincter

Small Intestine

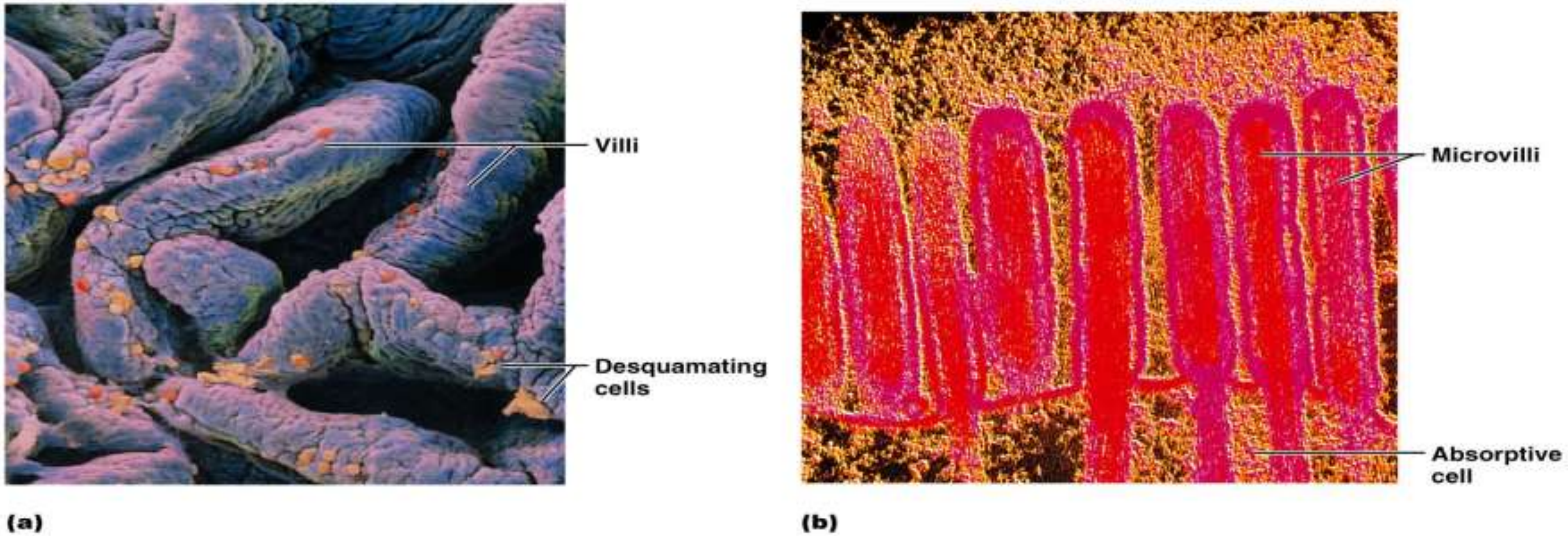
- A long tube, with a small diameter (about 1 inch), extending from pyloric sphincter to the ileocecal valve .
- Divided into **Duodenum**, **Jejunum**, and **ileum**.
- 1. Secretions of small intestine:
- a. Intestinal glands secrete a watery fluid that lack digestive enzymes but provides a vehicle for moving chyme to villi .Intestinal enzymes include : **maltase** digests maltose into glucose. **sucrose** digests sucrose into glucose and fructose . **lactase** digests sucrose into glucose and glucose. **peptidases** digest peptides into amino acids . **lipases** digest triglycerides into fatty acids and glycerol . **Nucleases** digest nucleotides into nitrogenous bases. **Enterokinase** converts trypsinogen into trypsin.

- b. Digestive enzymes embedded in the surfaces of microvilli split molecules of sugars, proteins and fats .
- c. Regulation of small intestine secretions: secretion is stimulated by gastric juice , chyme , and reflex stimulated by distension of the small intestinal wall .



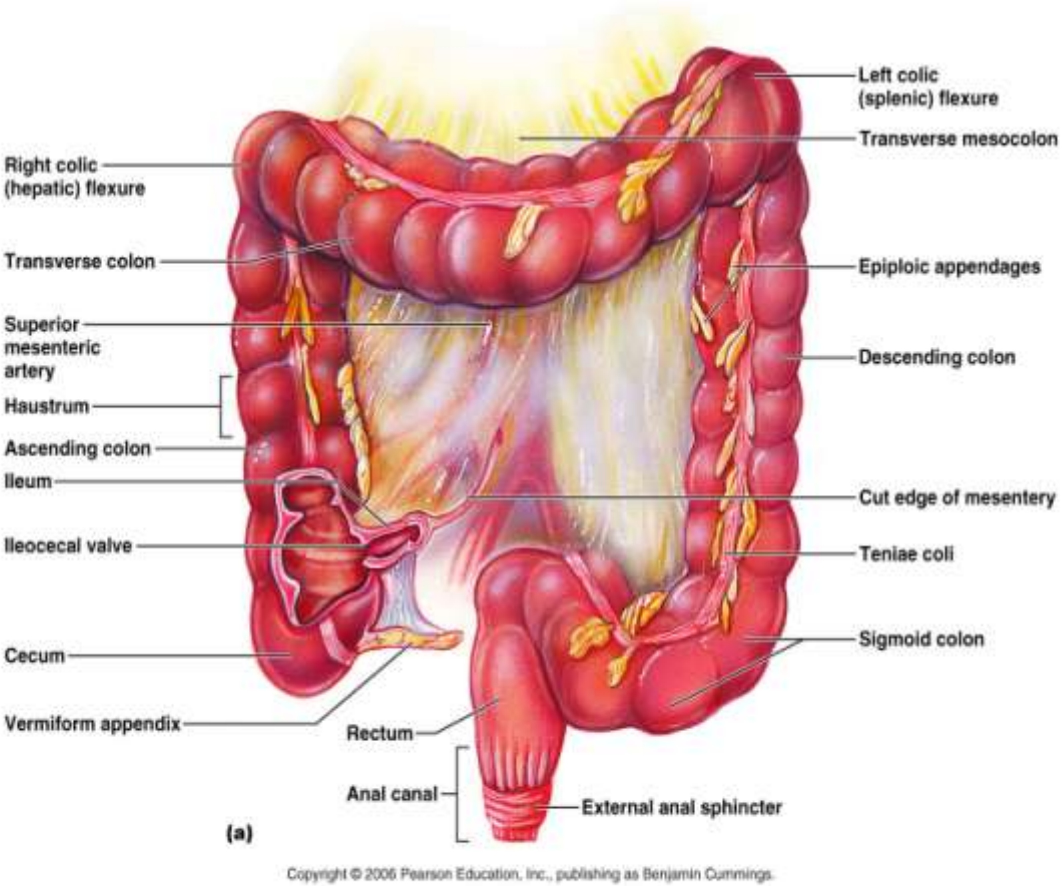
- d. Each villus contains blood capillaries to absorb water , glucose , amino acids , vitamins , minerals , and short-chain fatty acids , and also contains lymphatic capillaries called **lacteals** to absorb long – chain fatty acids in the forms of **micelles** .

- e. Water is absorbed by osmosis , fatty acids are absorbed by diffusion (since they are fat-soluble), and most other nutrients (glucose, amino acids, & minerals) are absorbed by active transport.



Large intestine

- The last segment of the GI tract , with a large diameter (2-3 inches) , extending from the ileocecal valve to the anus .
- Divided into **cecum , ascending colon , transverse colon , descending colon , sigmoid colon , rectum , anal canal** , and **anus.**



- The large intestine has little or no digestive function , although it secretes mucus. Its mucosa has no villa or microvillus , but cotains numerous **goblet cells** for secreting mucus to aid in the formation of feces and maintain an alkaline condition .
- mechanical stimulation and parasympathetic impulses control the rate of mucus secretion .
- The large intestine only absorbs **water**, electrolytes and some vitamins .
- Many **bacteria** inhabit the large intestine , where they break down certain indigestible substances and synthesize certain vitamins .
- feces are formed and stored in the large intestine . **Defecation** involves a reflex mechanism aided by voluntary contraction of the diaphragm , abdominal muscles ,and the external anal sphincter .

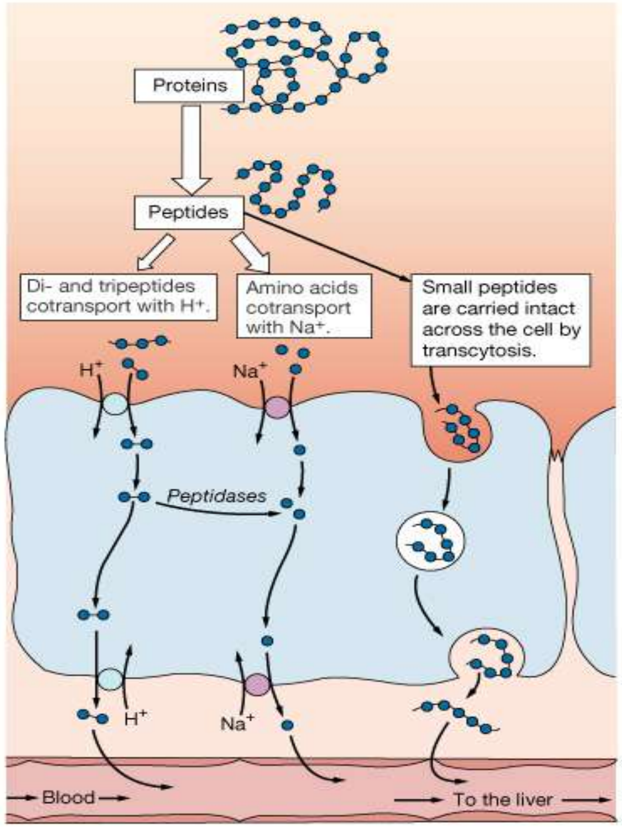
Major Hormones of The Digestive Tract

- 1. Gastrin : (Gastric & intestinal) : released by Gastric cells , in response to the presence of food. Causes Gastric glands to increase their secretory activity.
- 2. Somatostatin : (Gastric inhibitory peptides - GIP): Inhibits secretion of acid by parietal cells.
- 3. Cholecystokinin : released by intestinal wall cells , in response to the presence of proteins and fats in the small intestine. It causes gastric glands to decrease their secretory activity and inhibits gastric motility ; stimulation of pancreas to secrete digestive enzyme; stimulates gall – bladder to contract and release bile.
- 4. Secretin: released by cells in the duodenal wall, in response to acidic chyme entering the small intestine.

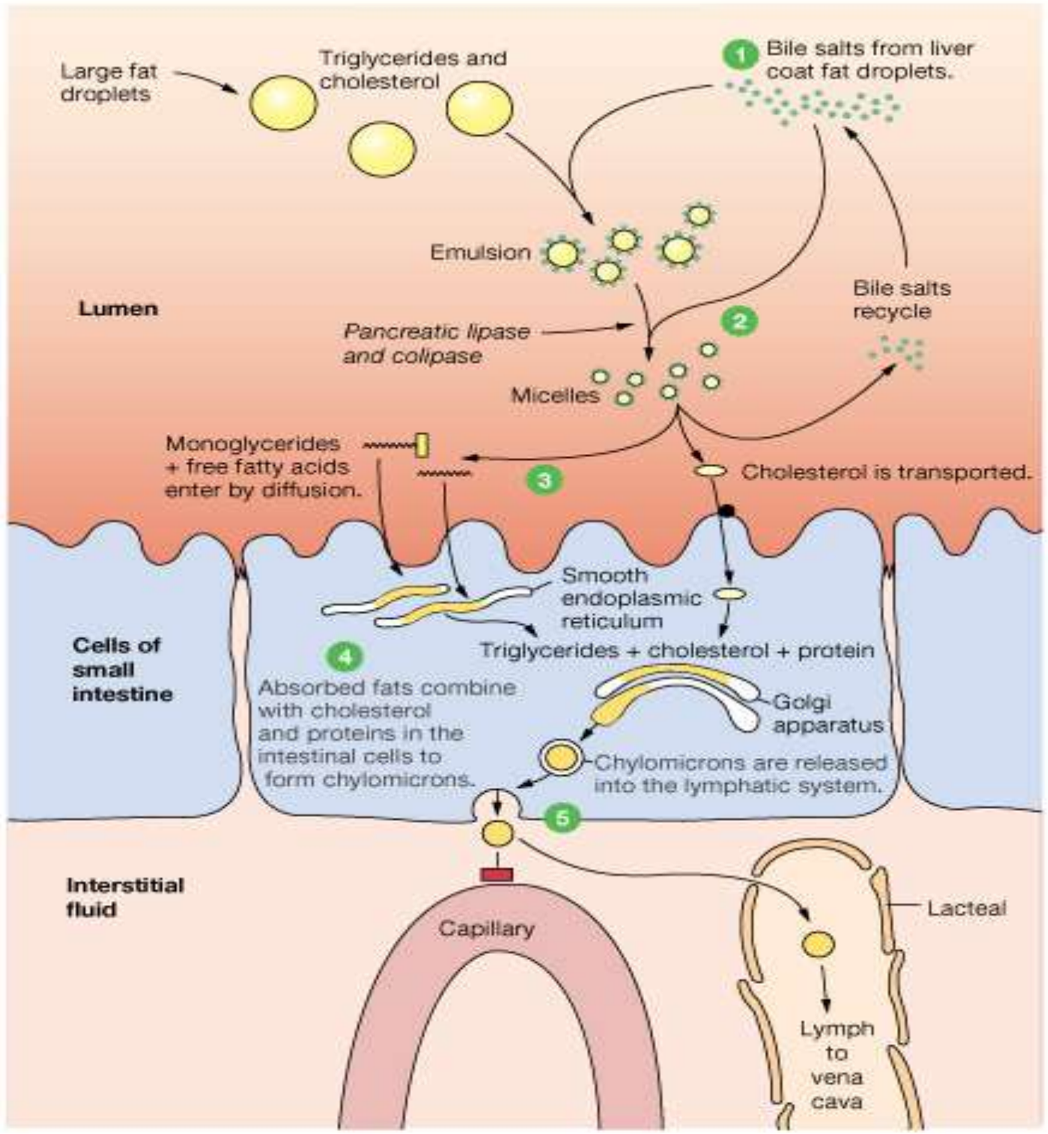
Major Digestive Enzyme

- **Salivary enzyme**: Begins carbohydrates digestion by breaking down starch and glycogen to disaccharides
- **Gastric enzymes**: Pepsin , from Gastric glands – Begins protein digestion . Lipase, from Gastric glands – Begins fat digestion .
- **Pancreatic enzymes**: Amylase , from pancreas – breaks down starch and glycogen into disaccharides. Lipase, from pancreas – breaks down fats into fatty acids and glycerol .
- **Proteolytic enzymes** :
  - Trypsin, Chymotrypsin, and Carboxypeptidase from pancreas breaks down peptides into amino acids . Nucleases, from pancreas- breaks down nucleic acids into nucleotides.

- **Intestinal Enzymes**: Peptidase, from mucosal cells, breaks down peptides into amino acids. Sucrase, maltase, and lactase , from mucosal cells, breaks down disaccharides into monosaccharides. Lipase, from mucosal cells, breaks down fats into fatty acid and glycerol. Enterokinase , from mucosal cells, (breaks down) converts trypsinogen into trypsin .



Fat digestion & Absorption



Clinical Terms

- **Achalasia** : failure of the smooth muscle to relax at some junction in the digestive tube.
- **Cholecystitis** : Inflammation of the gallbladder.
- **Chloelithiasis** : stones in the gallbladder.
- **Cholestasis** : Blockage in bile flow from the gallbladder.
- **Cirrhosis** : liver cells degenerate and the surrounding connective tissue thicken.
- **Diverticulitis** : Inflammation of small pouches that sometimes form in the lining and wall of the colon.
- **Dysentery** : Intestinal infection.

Clinical terms

- **Dyspepsia**: Indigestion
- **Dysphasia**: Difficulty in swallowing
- **Enteritis**: Inflammation of the intestine .